ASSISTING LEARNER'S IN MONITORING THEIR CONCEPTUAL DEVELOPMENT

On the design of a computer-based service to support conceptual development

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Abstract: This paper elaborates on the design of a computer-based service to support conceptual development. Our ambition is provide learners a way to compare their conceptual development against different reference models, so they recognize the limits of their expertise. These models are (semi) automatically generated from learning materials and learner text inputs using Latent Semantic Analysis, a technique that can identify the concepts and their relations between the concepts contained in input text materials. The paper explains the envisioned service presenting a scenario that illustrates how it can be used in formal and informal learning context. After, the paper elaborates the theoretical background behind the design of the service and, finally, it draws conclusions and outlines future work.

1 INTRODUCTION

Modern educational approaches stress the importance of activities such as problem based learning, joint presentations, discussions, collaborative knowledge co-construction and so on. These activities often are assessed on the joint group's performance, instead of on the individual learner's performance. This makes it difficult for individual learners to recognise their personal understanding and knowledge of the topic of study. For that, learners need to receive formative feedback to identify the boundaries of their knowledge. Tutors will no always be able to provide that feedback due to workload. On the other hand, tutors require reliable means of analysing the progress of learners in order to provide appropriate guidance and feedback to each individual. A means of providing learners and tutors with a clear understanding of the group' and the individual learners' conceptual development, which is also economical with tutor's time, is therefore required.

This paper presents the design of a computer-based service aimed at supporting learners' conceptual development. The service is envisaged to communicate information to learners intended to engender the formation of an accurate, (targeted) conceptualization of a particular topic. The information should also allow the learners to improve their understanding of a topic without the immediate need for a tutor. The design of the service is theoretically grounded in expertise development seen as a knowledge building process that comprises both cognitive and social approaches.

The service is envisaged to process learner's textual inputs (i.e., knowledge evidences) and to return a graphical representation that reflects how a learner conceptualizes a topic in terms of concepts and their relations. Learners can then compare their topic representations against a group reference model, and/or a pre-defined reference model. The group

reference model is a representation of how peers conceptualize the topic, while the “pre-defined reference model” is a representation of how in learning materials or tutor notes the topic is conceptualized, which can be seen as representing the intended learning outcomes.
The service explained in this paper goes beyond existing approaches on measuring conceptual development (Clariana & Wallace, 2007; Jeong, 2008; Shute, 2008) as we attempt to derive the reference models and topic representations (semi)automatically. To this end Latent Semantic Analysis (Landauer *et al.*, 2007) will be explored in order to analyze (raw) text and extracting terms and relationships with respect to their relatedness in meaning, thereby enabling the generation of conceptualisation models. Afterwards, these models will be contrasted to obtain meaningful information on conceptual development.
The rest of this paper is structured as follows. First it presents a scenario to elucidate further the need to monitor one’s conceptual development and outlines how the proposed service will work, which is illustrated with a working prototype of the service. The scenario also describes how the service can be used in an informal learning situation. Next, the paper presents the theoretical underpinnings for the design of the service. Finally, it discusses related work and indicates opportunities for future work.

2 SCENARIO

Marion is a Medical Student in her third year of study. This week Marion is working together with a group of peers on a problem based case about “cervical dysplasia”. They have to collect related information, and discuss and agree on the diagnosis on the case. At the end of the activity, they have to present their results to their other peers. Learners are also asked to keep a learning diary in the shape of a blog to reflect on their learning. The learning activity goes well, but Marion is not sure that she grasps all the notions and concepts of the topic, and if her understanding of the topic corresponds to the level she is supposed to have reached at this point in her learning career.
She then decides to use the conceptual development monitoring service, which is a freely available widget that can be included in her Personal Learning Environment. Marion finds the entry “Oncology- 3rd year medical learners”, created before by her tutor Dr. Moon, to submit her learning evidences. She then submits the blog she wrote about cervical cancer.

After processing Marion’s blog entry, the service displays a topic representation graph that includes the concepts the blog entry contains and how these concepts are related. The graph uses colours to identify also different themes (i.e., clusters of concepts). Figure 1 shows an example of a representation graph. There Marion can see that in her blog entry she is relating, for instance, the concept of “Cancer” with “Prostate” and “Breast”. But also that the theme ‘Cancer” is closely related to the theme “Research”.

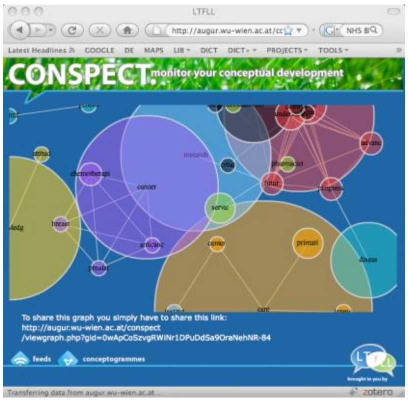

Figure 1. Example topic representation graph.

Marion can also compare her topic representation graph with other topic representation graphs. These representations can be, for instance, a group reference model (a graph that consists of all topic representations of her peers) or a predefined reference model, which represents the intended learning outcomes (a topic representation her tutor created using learning materials). For instance, Figure 2 shows the graph Marion sees when she compares her topic representation (in blue) with the tutor’s intended outcomes of the case about “cervical dysplasia” she was studying with her peers (in green). There it becomes evident to her that in her blog she is not mentioning topics related to cancer, such as the “Care” aspect (showed in the left top corner of the graph) and the “Keeping up to date” aspect (shown as ‘knowledge’ in the middle of the graph).
If Marion decides to ask Dr. Moon for feedback, she will make her topic representation public, so Dr. Moon can see it and provide feedback. If this is the case, Dr. Moon might explain to her that she should be more aware of the “Care” aspect, which includes “Diet”, but also “Cancer pharmacology’. She recommends Marion to read a book chapter as well as two journal articles Marion will find useful.
Marion can also use the service to compare her topic representation graph to that of any particular peer (of

the peers that have also made their representations public). The service also keeps a record of Marion's

Figure 2. Example comparison topic representation vs. predefined reference model.

topic representation graphs, so she can compare her representation graphs over time. This allows her to gain insight into her progress in understanding the topic. Figure 3 shows how Marion uses her topic representation graphs. In this view she can make graphs public and she can select which graphs she

would like to compare.

Figure 3. View of topic representations.

Marion likes the service, so she decides to introduce it in an informal learning context as well: the Latin American literature group she is part of. In this context she acts as tutor ("initiator") and creates a topic space for "magical realism" and sends an e-mail with the space' URL to her peers so they can access it. Her friends join and use the service to submit their knowledge evidences. Some of them submit a blog entry, while others decide to submit an essay they wrote about the topic. They work with the service to get topic representation graphs of their personal understanding side by side with their friend's representation graphs of the topic. As the service can create a topic representation graph that is based on all their joint submissions, they can, when they meet face-to-face, use that representation (the group reference model) to see and discuss their shared representation graph of the topic. They also have been using well-known literature about the topic to create a pre-defined reference model. This allows them to compare and discuss about the differences and similarities between the different models, namely their personal topic reference models, the group reference model, and the predefined reference model.

3 THEORETICAL BACKGROUND

The design of the service described above is underpinned by a theoretical background that considers the processes on which learners build their knowledge, as well as the effects this has on their knowledge structures~~,~~ in their development from novice to expert.

Research on expertise has shown differences in the knowledge base development between novice to expert (Boshuizen & Schmidt, 1992). Experts and novices differ in their knowledge usage, information processing, and on how their knowledge structures are organized (Arts *et al.*, 2006). Findings in Law (Nievelstein *et al.*, 2008), Physics (Dufresne *et al.*, 1992), Management (Arts *et al.*, 2006), and Medicine (van de Wiel *et al.*, 2000) have shown that knowledge, with increasing expertise, is more hierarchically structured, while novices' knowledge appears to be highly fragmented with concepts loosely connected.

Learners develop their expertise taking part in a knowledge building cycle, which comprises cognitive and social processes. A cognitive process focuses on perception, memory and meaning; it assumes the memory is an active processor of information, and knowledge, as a commodity plays an important role in learning. A social process assumes that learning is a social activity, which occurs in interaction with others. It takes into account both the learner and the environment, where learners are pro-active producers of the environment in which they operate.

The service presented above is designed to assist the learner in the development of their expertise from both a cognitive and social perspective. It provides learners with diverse ways of comparing their understanding against different models, mainly a (Berlanga *et al.*, 2009a):

(1) *Predefined reference model*, considering indented learning outcomes described in, for instance, course material, tutor notes, relevant papers.
(2) *Group reference model*, considering the concepts and the relations a group of people (e.g., peers, participants, co-workers, etc.) used the most.

The result is that, from a cognitive point of view, the service provides learners with information that contrasts their understanding of the topic against the intended learning outcomes. From a social point of view, the service provides information to learners so they recognize the differences in how they conceptualize a topic with respect to how others do.

Furthermore the service provides cultural and cognitive artifacts to support the knowledge building process. In this respect we base our work on Stahl's knowledge building cycle (Stahl, 2006). Following a social epistemological perspective (Brown & Duguid, 1991; Lave & Wenger, 1991), Stahl models the learning process as a mutual construction of the individual and the social knowledge building. In his view knowledge is a socially mediated product. Individuals generate personal beliefs from their own perspectives, but they do so on the basis of socio-cultural knowledge, shared language and external representations. These beliefs become knowledge through social interaction, communication, discussion, clarification and negotiation. Learners, therefore, build knowledge both personally and collaboratively.

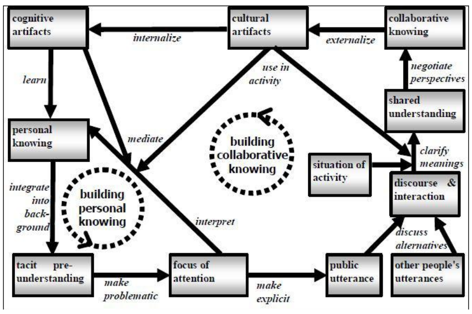

Figure 4. Cycle of knowledge building (Stahl, 2006).

Figure 4 shows Stahl's cycle of knowledge building. The diagram depicts how the personal and the collaborative knowing building cycles interact.

The lower left corner shows the cycle of personal understanding, which might start with a tacit pre-understanding influenced by personal knowing. This understanding may change if we explicate the implications of that understanding and resolve conflicts or fill gaps—by reinterpreting our meaning structures—to arrive at a new comprehension. This typically involves some feedback from e.g., our experience with artifacts such as our tools and symbolic representations. New comprehension gradually settles in to become our new tacit understanding and provides the starting point for future understanding and further learning. If we cannot resolve the problematic character of our personal understanding alone, which happens mostly when it is provoked by other people, then we need to enter into an explicitly social process and create new meaning collaboratively. To do this, we typically articulate our initial belief in words and express ourselves in public statements, and we enter into the cycle of social knowledge building.

The right part of the diagram depicts how the social process of interaction with people and with our shared culture influences the individual's understanding. This process is an interchange of arguments that provide rationales for different points of view, which eventually may converge on a shared understanding, resulting from a clarification of differences in interpretation and terminology. Although in the diagram personal cognition and social activity are depicted separately, this is only a matter of representation; they can only be separated artificially.

Our service design aims at supporting both knowledge building cycles. On the left hand side of the cycle, it provides a cognitive artifact (i.e., a graph representing learner's topic representation) that can help learners to understand and resolve conflicts or fill in gaps in their knowledge. If this is not possible, learners enter into the cycle of social knowledge building. In this cycle, the service provides a 'cultural artifact' (i.e. a graph that contains the intended learning outcomes or a single graph that is based on all peers graphs) that can help to foster understanding.

Regarding how the service can be deployed in an educational context, if a cognitive or a social perspective should be followed, it is important to stress that many educational practices start by providing learners with explicit knowledge, and only after learners have gathered what is considered a critical mass of that knowledge, they allow learners to acquire implicit, experiential, applied knowledge. Likewise, to develop stimulating and suitable instructional strategies, the instructional approach needs to take into account whether learners are novice or experts,. Researchers on instructional design (Ertmer & Newby, 1993; Jonassen *et al.*, 1993) do not advocate a single theory of learning, but emphasise that the instructional strategy and the content addressed depend on the learner's expertise level. They claim, therefore, that behavioural strategies can facilitate mastery of the content of a profession (knowing what); that cognitive strategies are useful for acquiring procedural knowledge (knowing how); and that constructivist strategies are appropriate when dealing with ill-defined problems, as summarized in Figure 5.

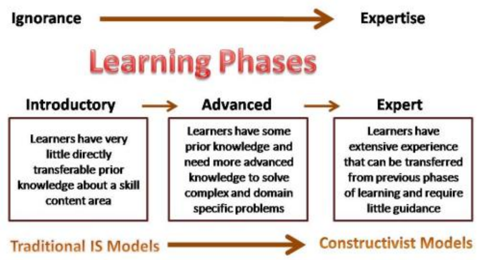

Figure 5. The Continuum of Knowledge Acquisition Model (Jonassen et al., 1993).

4 CONCLUSIONS AND FUTURE WORK

In this paper we introduced a computer-based service designed to help learners to monitor their conceptual development. Our ambition is to develop a service that requires minimal human pre-configuration, which automatically –using Latent Semantic Analysis– identifies the concepts, the relation between the concepts in learning materials and learner provide materials, and provides learners/participants with a way to compare their topic representations with other models. We have elaborated on a use case that explains how the service will work, and we have explained the theoretical foundations behind the design of the service. Particularly, we discussed how the design of the service is grounded in findings in the expertise development area and on a knowledge building model. We also elaborated on how the service can be used in educational contexts.

It is important to stress that a lifelong learning perspective was also considered on the design of the service. That is to say the service is designed in a way that can be used only for personal use, or in formal or informal learning situations. A personal use of the service, learners will not share their representations, but still will get information on how they conceptualize a topic, create reference models, and compare them. In a formal learning context, tutors can create reference models and the service can provide information to both tutors and learners. In informal learning situations, the service can be used by a group of people, not guided by a tutor, to share their knowledge and reach a common understanding.

Up to now, existing tools and software that identify and approximate learner's conceptual development have been explored, and a proof-of-concept has been conducted to demonstrate the generation of reference models (Berlanga *et al.*, 2009b).

Undoubtedly, more research is needed to establish how learners would benefit the most from comparing their conceptual development with the proposed models (pre-defined reference model or group model): whether it is good strategy for learners to see comparisons with both models or, whether, depending on their level of expertise, comparisons with different models will be made available. The type of reference model used may depend on the level of learner development. The emerging reference model, which is based on concepts and their interrelationships, generated by peers, would most likely be of use for an individual learner at a novice level, as at this stage it would correspond to his/her Zone of Proximal Development (Vygotsky, 1978). As expertise develops, the emerging reference models may still be appropriate, depending on the development stage of the group as a whole, but pre-defined reference models may be more suited to a more advanced learner.

To ensure quality and applicability of our service, we use a scenario-based design methodology (Hensgens *et al.*, 2009) which requires conceptual validation with stakeholders and formative evaluation of the service. To this end a validation with stakeholders from the Medical School, Manchester University will be conducted. The feedback received will be adopted to design the first version of the service. This version will be then evaluated, using primarily qualitative methods, and the results will be considered to develop a new release of the service.

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